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X-ray Standing Wave Studies of Si/Ge/Si(001) Heterostructures

B. Tinkham (Northwestern U.), D. Goodner (Northwestern U.), M. Bedzyk (Northwestern U. and ANL)
Beamline(s): X15A

Introduction: X-ray standing waves have been used to investigate the quality of epitaxial ultra-thin Ge films grown on Si(001) with and without Te as a surfactant. It is known that at approximately 3 ML Ge ceases to grow layer-by-layer and begins instead to form islands on Si(001). If a surfactant is used during Ge growth it is possible to extend this critical thickness well past 3ML. The efficacy of Te as a surfactant in this application has been debated. By comparing the coherent fraction and position of films grown with and without Te we can make a quantitative measure of the degree to which the use of Te enhances epitaxial growth.

Methods and Materials: The Si/Ge/Si(001) films were grown by molecular beam epitaxy in a UHV system with a base pressure lower than 1×10^{-10} Torr. The Si substrates were cleaned by the Shiraki Method and subsequently flashed to 800°C until a sharp 2×1 LEED pattern was observed. Ge and Te were evaporated simultaneously with the Si(001) substrate held at 410°C . The thickness of the Ge layers varied between 1ML and 15ML and were grown with and without Te used as a surfactant. Finally a 100 Å Si Cap was evaporated at a substrate temperature of 410° with or without a Te overpressure. The Si Cap was necessary in order to prevent oxidation of the Ge epitaxial layer after removal from the vacuum chamber. The samples were measured in open-air at the X15A beamline. The XSW scans were made by monitoring the Ge $K\alpha$ fluorescence signal while scanning in energy though either the Si(004) or Si(022) rocking curves. The coherent fraction and coherent position of the atoms in the Ge film with respect to the Si(001) substrate was then determined by applying dynamical diffraction theory analysis to the data.

Results: Figure 1 compares the florescence fits from samples of similar Ge thickness grown with and without Te as a surfactant. Sample (a) is a 3.4 Ge ML film grown with Te as a surfactant while sample (b) is a 2.65 ML film grown with no surfactant. The fact that the sample grown with surfactant is thicker, yet has a higher coherent fraction (0.88 vs 0.65) suggests that Te has succeeded in improving the epitaxial quality of the Ge epilayer.

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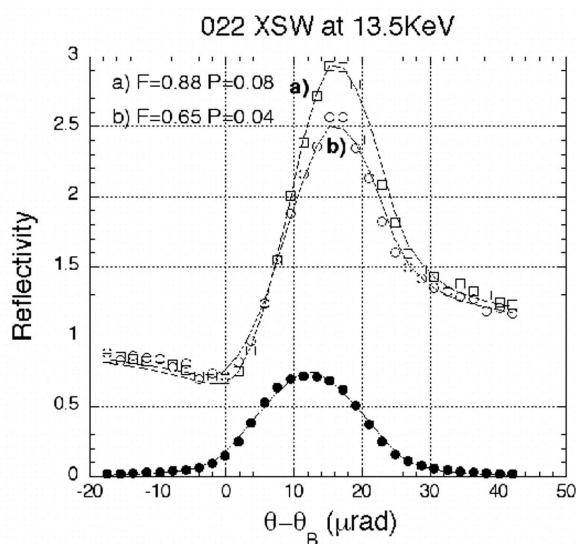


Figure 1